

## STEPPER MOTOR DRIVER

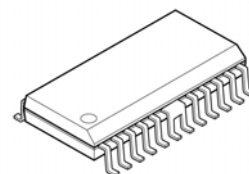
### ■ GENERAL DESCRIPTION

The NJM2673 is a stepper motor driver, which consists of a LS-TTL compatible logic input stage, off time control circuits and a pair of high power H-bridges and protection diodes.

The output current is up to 1000mA.

The NJM2673 with small number of external components conforms a complete control and drive unit for stepper motor systems.

### ■ PACKAGE OUTLINE



**NJM2673E3**  
( SOP24 )

### ■ FEATURES

- Switched mode bipolar constant current drive
- Wide voltage range 4 to 45V
- Wide range of current control 5 to 1000mA
- Half- step and full-step operation
- Thermal overload protection
- Package SOP24 JEDEC 300mil (batwing)

### ■ PIN CONNECTION

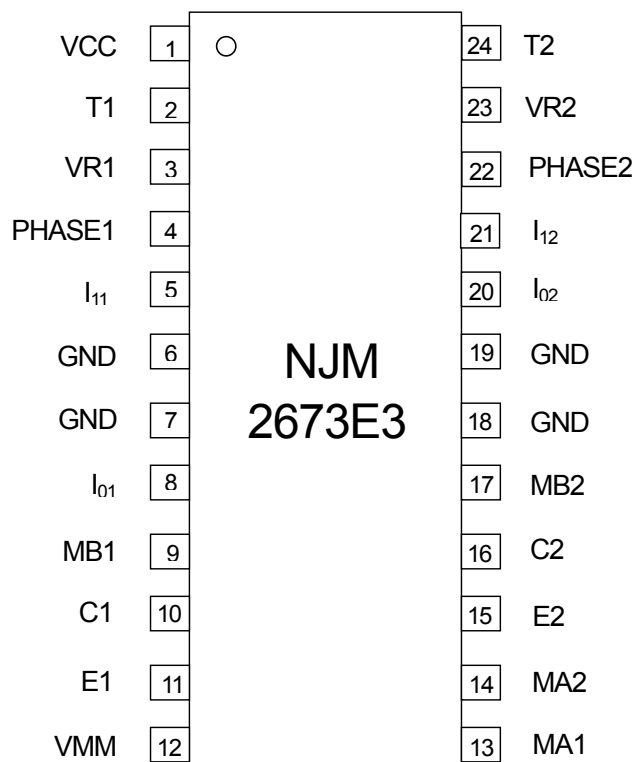


Figure1. Pin configuration

■ BLOCK DIAGRAM

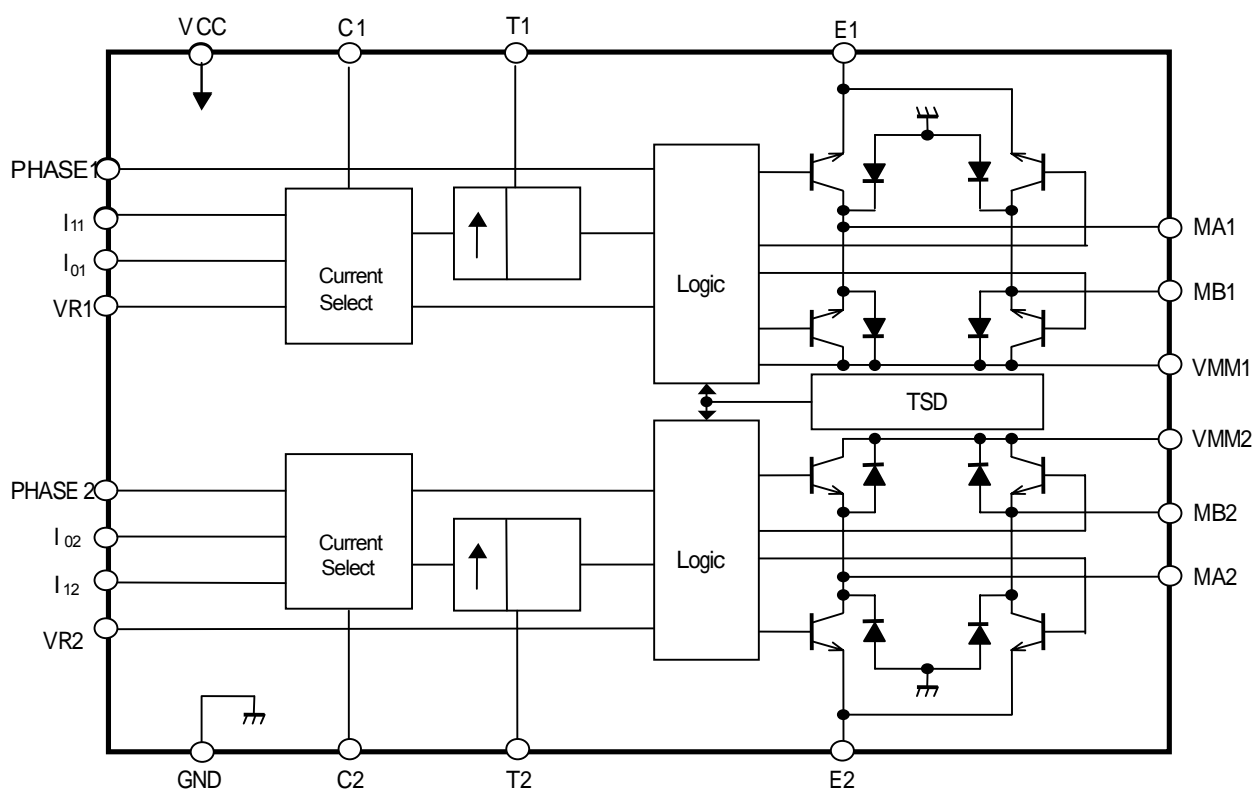


Figure 2. Block Diagram

## ■ PIN DESCRIPTION

SOP	Symbol	Description
1	V <sub>CC</sub>	Logic voltage supply normally +5V.
2	T1	Clock Oscillator, channel 1. Timing pin connect a 56kΩ resistance and a 820pF in parallel between T and ground.
3	VR1	Reference voltage, channel 1. Controls the threshold voltage for the comparator and hence the output current.
4	PHASE1	Controls the direction of the motor current of MA1 and MB1 outputs. Motor current flows from MA1 to MB1 when Phase1 is HIGH.
5	I <sub>11</sub>	Logic input, channel 1. It controls, together with the I <sub>01</sub> input, the current level in the output stage.
6,7,18,19	GND	Ground and negative supply. These pins are used for heat sinking. Make sure that all ground pins are soldered onto a suitable large copper ground plane for efficient heat sinking.
8	I <sub>01</sub>	Logic input, channel 1. It controls, together with the I <sub>11</sub> input, the current level in the output stage.
9	MB1	Motor output B, channel 2. Motor current flows from MA1 to MB1 when Phase1 is high.
10	C1	Comparator input, channel 1. This input senses the instantaneous voltage across the sensing resistor, filtered through a RC network.
11	E1	Common emitter, channel 1. Connect the Sense resistor between this pin and ground.
12	VMM	Motor supply voltage, 4 to 40V.
13	MA1	Motor output A, channel 1. Motor current flows from MA1 to MB1 when Phase1 is high.
14	MA2	Motor output A, channel 2. Motor current flows from MA2 to MB2 when Phase2 is high.
15	E2	Common emitter, channel 2. Connect the Sense resistor between this pin and ground.
16	C2	Comparator input, channel 2. This input senses the instantaneous voltage across the sensing resistor, filtered through a RC network.
17	MB2	Motor output B, channel 2. Motor current flows from MA2 to MB2 when Phase2 is high.
20	I <sub>02</sub>	Logic input, channel 2. It controls, together with the I <sub>12</sub> input, the current level in the output stage.
21	I <sub>12</sub>	Logic input, channel 2. It controls, together with the I <sub>02</sub> input, the current level in the output stage.
22	PHASE2	Controls the direction of the motor current of MA2 and MB2 outputs. Motor current flows from MA2 to MB2 when Phase2 is HIGH.
23	VR2	Reference voltage, channel 2. Controls the threshold voltage for the comparator and hence the output current.
24	T2	Clock Oscillator, channel 2. Timing pin connect a 56kΩ resistance and a 820pF in parallel between T and ground.

## ■ ABSOLUTE MAXIMUM RETINGS

(Ta=25°C)

# NJM2673

PARAMETER	SYMBOL	MIN.	MAX.	UNIT
<b>Voltage</b>				
Logic Supply	$V_{CC}$	0	7	V
Motor Supply	$V_{MM}$	0	45	V
Logic Input Voltage	$V_I$	-0.3	$V_{CC}$	V
Comparator Input Voltage	$V_C$	-0.3	$V_{CC}$	V
Reference Input Voltage	$V_C$	-0.3	$V_{CC}$	V
<b>Current</b>				
Motor Output Current	$I_M$	-1000	+1000	mA
Logic Input Current	$I_I$	-10	-	mA
Analog Input Current	$I_A$	-10	-	mA
<b>Temperature</b>				
Operating Temperature	$T_{opr}$	-40	85	°C
Storage Temperature	$T_{stg}$	-55	150	°C

## ■ RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
Logic Supply	$V_{CC}$	4.75	5.00	5.25	V
Motor Supply	$V_{MM}$	4	-	40	V
Motor Output Current	$I_M$	-800	-	800	mA
Operating Junction Temperature	$T_J$	-20	-	+125	°C
Rise time Logic Inputs	$t_r$	-	-	2	μS
Fall Time Logic Inputs	$t_f$	-	-	2	μS

## ■ ELECTRICAL CHARACTERISTICS (T<sub>J</sub>=+25°C, V<sub>CC</sub>=5V, V<sub>MM</sub>=40V, C<sub>T</sub>=820pF, R<sub>T</sub>=56kΩ)

PARAMETER	SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
<b>General</b>						
Supply Current	I <sub>CC</sub>		-	-	60	mA
Turn Off	t <sub>d</sub>	dV <sub>c</sub> /dt≥50mV/μs	-	0.9	-	μs
Thermal Shutdown Temperature	TSD		-	170	-	°C
<b>Logic Input</b>						
H Level Input Voltage	V <sub>IH</sub>		2.0	-	-	V
L Level Input Voltage	V <sub>IL</sub>		-	-	0.8	V
H Level Input Current	I <sub>IH</sub>	V <sub>i</sub> =2.4V	-	-	20	μA
L Level Input Current	I <sub>IL</sub>	V <sub>i</sub> =0.4V	-250	-	-	μA
<b>Input Resistance</b>						
Input Resistance	R <sub>R</sub>		-	8.8	-	kΩ
<b>Analog Input</b>						
Threshold Voltage	V <sub>CH</sub>	V <sub>R</sub> =5.0V, I <sub>0</sub> =I <sub>1</sub> =L	405	450	495	mV
	V <sub>CM</sub>	V <sub>R</sub> =5.0V, I <sub>0</sub> =H, I <sub>1</sub> =L	284	315	347	mV
	V <sub>CL</sub>	V <sub>R</sub> =5.0V, I <sub>0</sub> =L, I <sub>1</sub> =H	134	150	163	mV
Input Current	I <sub>C</sub>		-20	-	-	μA
<b>Motor Output</b>						
Lower Transistor Saturation Voltage	V <sub>OL</sub>	I <sub>M</sub> =500mA	-	1.1	1.4	V
		I <sub>M</sub> =800mA	-	1.3	1.7	V
Upper Transistor Saturation Voltage	V <sub>OU</sub>	I <sub>M</sub> =500mA	-	1.1	1.4	V
		I <sub>M</sub> =800mA	-	1.3	1.7	V
Lower Diode Forward Voltage Drop	V <sub>FL</sub>	I <sub>M</sub> =500mA	-	1.0	1.3	V
		I <sub>M</sub> =800mA	-	1.2	1.6	V
Upper Diode Forward Voltage Drop	V <sub>IU</sub>	I <sub>M</sub> =500mA	-	1.1	1.4	V
		I <sub>M</sub> =800mA	-	1.3	1.7	V
Output Leak Current	I <sub>IL</sub>	I <sub>0</sub> =I <sub>1</sub> =H	-	-	100	μA
<b>Monostable</b>						
Cut Off Time	t <sub>off</sub>		-	31	-	μs

## ■ THERMAL CHARACTERISTICS

PARAMETER	SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Thermal Resistance	R <sub>thJ-GND</sub>		-	13	-	°C
	R <sub>thJ-A</sub>	Note2	-	42	-	°C

### Notes

1. All voltages are with respect to ground. Currents are positive into, negative out of specified terminal.
2. All ground pins soldered onto 20cm<sup>2</sup> PCB copper area with free air condition, T<sub>A</sub>=25°C.

# NJM2673

## ■ TYPICAL APPLICATION CIRCUIT

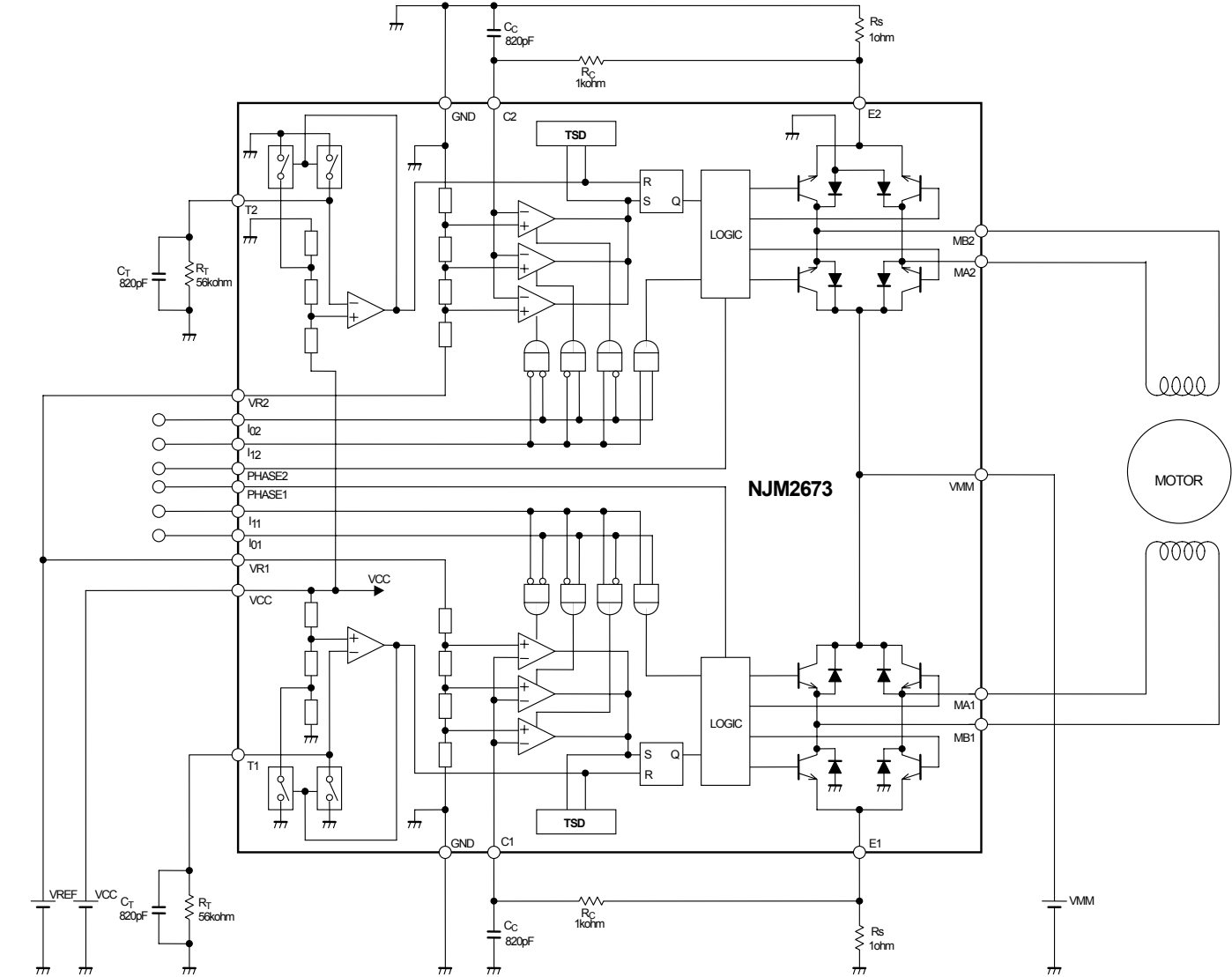
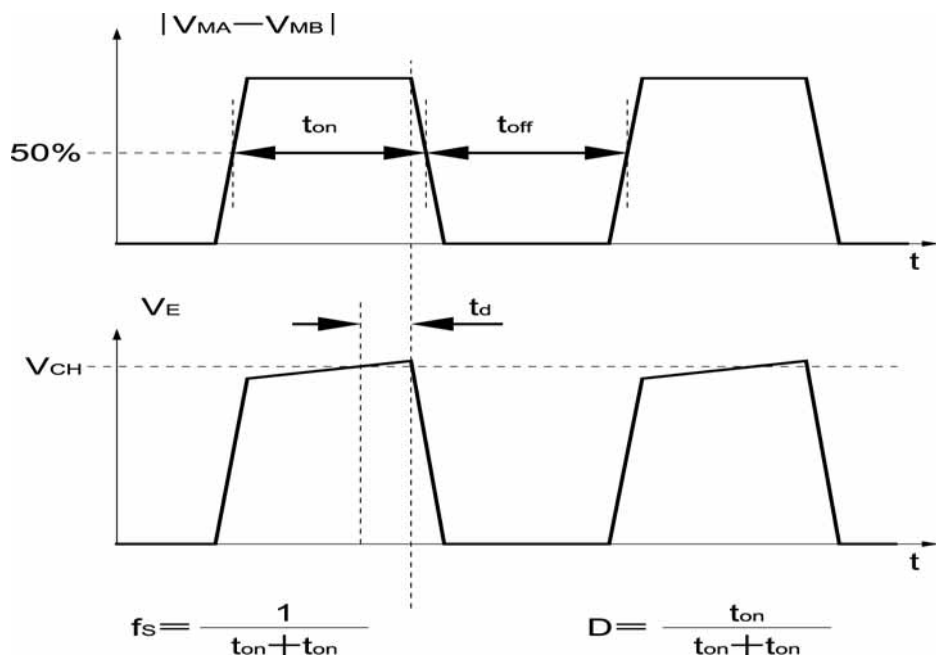


Figure 3. Application Circuit

## ■ TYPICAL APPLICATION CIRCUIT



## FUNCTIONAL DESCRIPTION

The NJM2673 is intended to drive a bipolar constant current through one winding of a 2-phase stepper motor.

Current control is achieved through switched-mode regulation, see figure 4 and 5.

Three different current levels and zero current can be selected by the input logic.

The circuit contains the following functional blocks:

- Input logic
- Current sense
- Single-pulse generator
- Output stage

### Input logic

#### Phase input

The phase input determines the direction of the current in the motor winding. High input forces the current from terminal  $M_A$  to  $M_B$  and low input from terminal  $M_B$  to  $M_A$ . A Schmitt trigger provides noise immunity and a delay circuit eliminates the risk of cross conduction in the output stage during a phase shift.

Half- and full-step operation is possible.

### Current level selection.

The status of  $I_0$  and  $I_1$  inputs determines the current level in the motor winding. Three fixed current levels can be selected according to the table below.

Motor current		$I_0$	$I_1$
High level	100%	L	L
Medium level	60%	H	L
Low level	20%	L	H
Zero current	0%	H	H

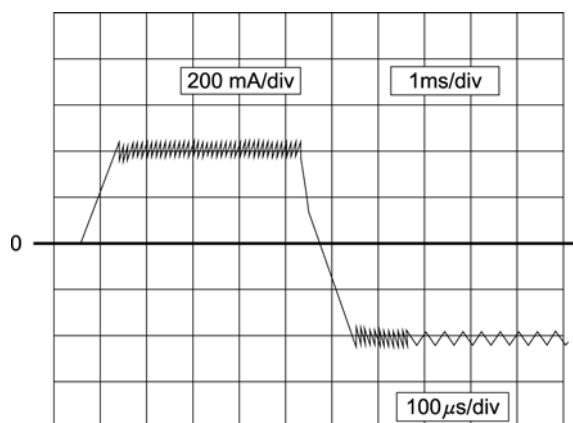


Figure 4. Motor current ( $I_M$ ),  
Vertical : 200 mA/div,  
Horizontal: 1 ms/div,  
expanded part 100  $\mu$ s/div.

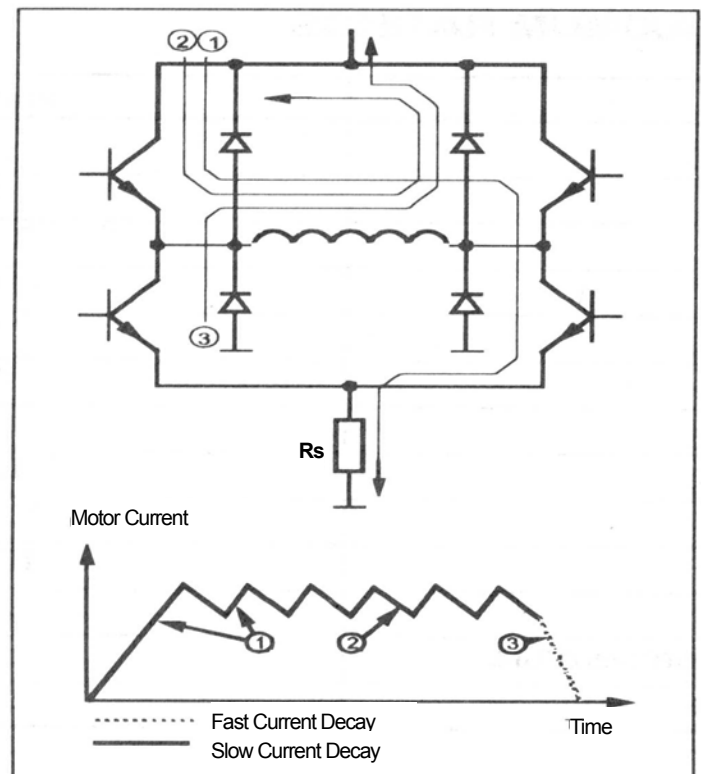


Figure 5. Output stage with current paths for fast and slow current decay.

The specific values of the different current levels are determined by the reference voltage  $V_R$  together with the value of the sensing resistor  $R_S$ .

The peak motor current can be calculated as follows:

$$i_m = (V_R \cdot 0.080) / R_S \text{ [A], at 100% level}$$

$$i_m = (V_R \cdot 0.050) / R_S \text{ [A], at 60% level}$$

$$i_m = (V_R \cdot 0.016) / R_S \text{ [A], at 20% level}$$

The motor current can also be continuously varied by modulating the voltage reference input.

## Current sensor

The current sensor contains a reference voltage divider and three comparators for measuring each of the selectable current levels. The motor current is sensed as a voltage drop across the current sensing resistor,  $R_S$ , and compared with one of the voltage references from the divider. When the two voltages are equal, the comparator triggers the single-pulse generator. Only one comparator at a time is activated by the input logic.

## Single-pulse generator

The pulse generator is a monostable multivibrator triggered on the positive edge of the comparator output. The multivibrator output is high during the pulse time,  $t_{off}$ , which is determined by the timing components  $R_T$  and  $C_T$ .

The single pulse switches off the power feed to the motor winding, causing the winding to decrease during  $t_{off}$ .

If a new trigger signal should occur during  $t_{off}$ , it is ignored.

## Output stage

The output stage contains four transistors and four diodes, connected in an H-bridge. Note that the upper recirculation diodes are connected to the circuit externally. The two sinking transistors are used to switch the power supplied to the motor winding, thus driving a constant current through the winding. See figures 4 and 5.

## Overload protection

The circuit is equipped with a thermal shut-down function, which will limit the junction temperature. The output current will be reduced if the maximum permissible junction temperature is exceeded. It should be noted, however, that it is not short circuit protected.

## Operation

When a voltage  $V_{MM}$  is applied across the motor winding, the current rise follows the equation:

$$i_m = (V_{MM} / R) \cdot (1 - e^{-(R \cdot t) / L})$$

$R$  = Winding resistance

$L$  = Winding inductance

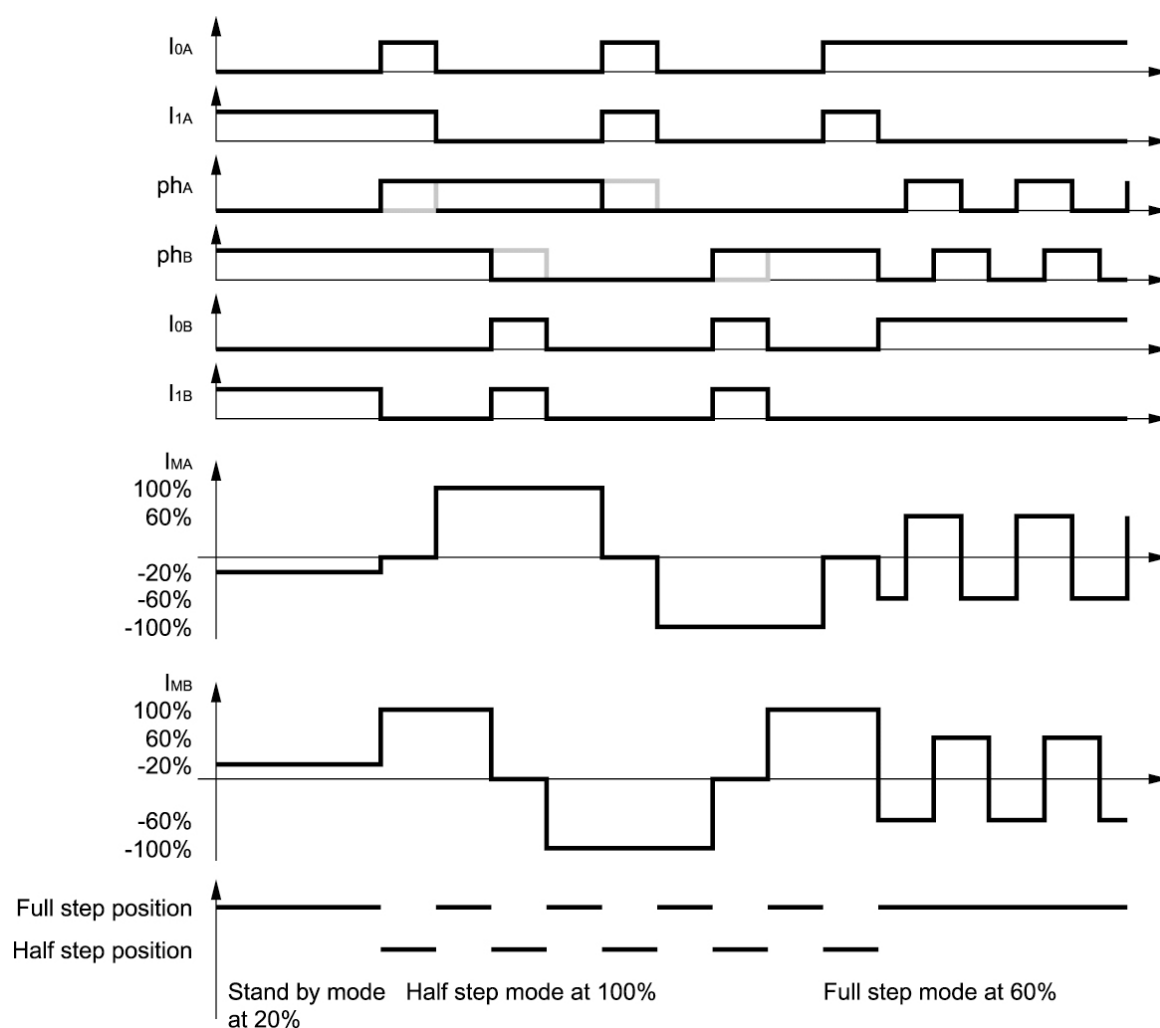
$t$  = time

(see figure 5, arrow 1)

The motor current appears across the external sensing resistor,  $R_S$ , as an analog voltage. This voltage is fed through a low-pass filter,  $R_C C_C$ , to the voltage comparator input (pin 10 and pin 16). At the moment the sensed voltage rises above the comparator threshold voltage, the monostable is triggered and its output turns off the conducting sink transistor. The polarity across the motor winding reverses and the current is forced to circulate through the appropriate upper protection diode back through the source transistor (see figure 5, arrow 2).

After the monostable has timed out, the current has decayed and the analog voltage across the sensing resistor is below the comparator threshold level. The sinking transistor then turns on and the motor current starts to increase again. The cycle is repeated until the current is turned off via the logic inputs. When both  $I_1$  and  $I_0$  are high, all four transistors in the output H-bridge are turned off, which means that inductive current recirculates through two opposite free-wheeling diodes (see figure 5, arrow 3). This method of turning off the current results in a faster current decay than if only one transistor was turned off and will therefore improve speed performance in half-stepping mode.

## ■ PRINCIPAL OPERATING SEQUENCE



## ■ APPLICATIONS INFORMATION

### Motor selection

Some stepper motors are not designed for continuous operation at maximum current. As the circuit drives a constant current through the motor, its temperature can increase, both at low- and high-speed operation.

Some stepper motors have such high core losses that they are not suited for switched-mode operation.

### Interference

As the circuit operates with switched-mode current regulation, interference-generation problems can arise in some applications. A good measure is then to decouple the circuit with a 0.1  $\mu\text{F}$  ceramic capacitor, located near the package across the power line VMM and ground.

Also make sure that the  $V_{\text{Ref}}$  input is sufficiently decoupled. An electrolytic capacitor should be used in the +5V rail, close to the circuit.

The ground leads between  $R_S$ ,  $C_C$  and circuit GND should be kept as short as possible. This applies also to the leads connecting  $R_S$  and  $R_C$  to pin 10 and pin 11, pin 15 and pin 16 respectively.

In order to minimize electromagnetic interference, it is recommended to route  $M_A$  and  $M_B$  leads in parallel on the printed circuit board directly to the terminal connector. The motor wires should be twisted in pairs, each phase separately, when installing the motor system.

### Unused inputs

Unused inputs should be connected to proper voltage levels in order to obtain the highest possible noise immunity.

### Ramping

A stepper motor is a synchronous motor and does not change its speed due to load variations. This means that the torque of the motor must be large enough to match the combined inertia of the motor and load for all operation modes. At speed changes, the required torque increases by the square, and the required power by the cube of the speed change. Ramping, i.e., controlled acceleration or deceleration must then be considered to avoid motor pullout.

### VCC , VMM

The supply voltages, VCC and VMM, can be turned on or off in any order. Normal  $dv/dt$  values are assumed.

Before a driver circuit board is removed from its system, all supply voltages must be turned off to avoid destructive transients being generated by the motor.

### Switching frequency

The motor inductance, together with the pulse time,  $t_{\text{off}}$ , determines the switching frequency of the current regulator. The choice of motor may then require other values on the  $R_T$ ,  $C_T$  components than those recommended in figure 3, to obtain a switching frequency above the audible range. Switching frequencies above 40 kHz are not recommended because the current regulation can be affected.

### Analog control

As the current levels can be continuously controlled by modulating the  $V_R$  input, limited microstepping can be achieved.

### Sensor resistor

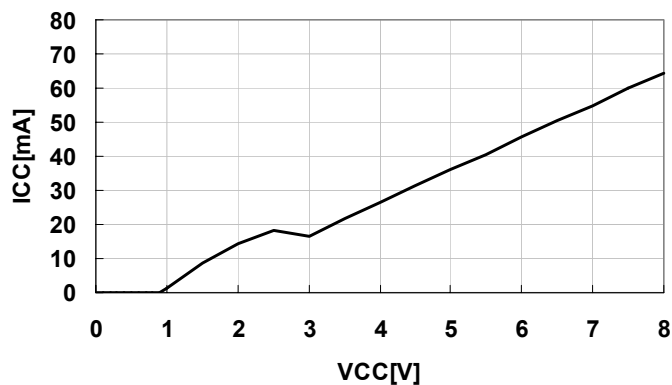
The  $R_S$  resistor should be of a noninductive type power resistor. A 1.0 ohm resistor, tolerance  $\leq 1\%$ , is a good choice for 415 mA max motor current at  $V_R = 5\text{V}$ .

The peak motor current,  $i_m$ , can be calculated by using the formula:

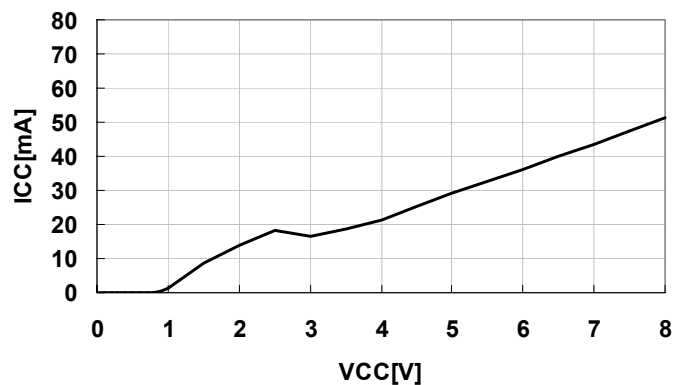
$$i_m = (V_R \cdot 0.080) / R_S [\text{A}], \text{ at } 100\% \text{ level}$$

## ■ TYPICAL CHARACTERISTICS

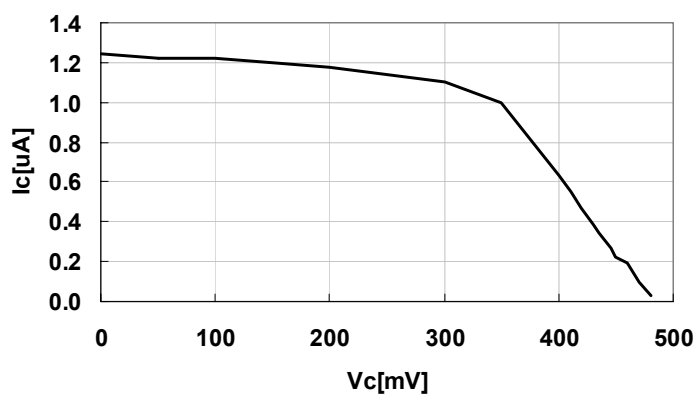
VCC VS. ICC  
@NJM2673 I<sub>0</sub>=I<sub>1</sub>=LOW



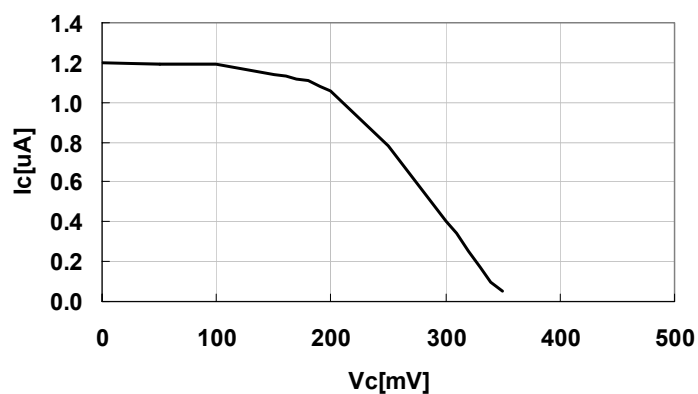
VCC VS. ICC  
@NJM2673 I<sub>0</sub>=I<sub>1</sub>=HIGH



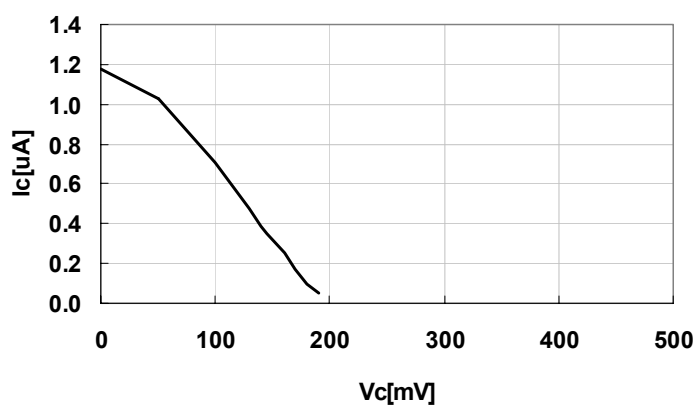
COMP input Voltage VS. COMP input Current  
@NJM2673 VCC=VR=5V I<sub>0</sub>=I<sub>1</sub>=LOW



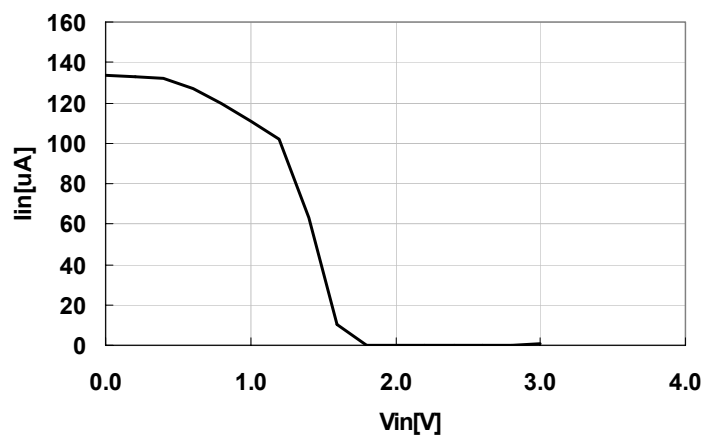
COMP input Voltage VS. COMP input Current  
@NJM2673 VCC=VR=5V I<sub>0</sub>=LOW I<sub>1</sub>=HIGH



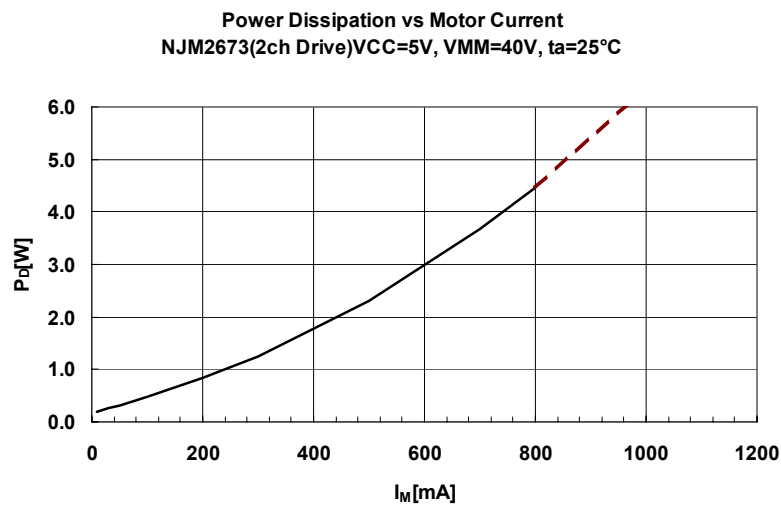
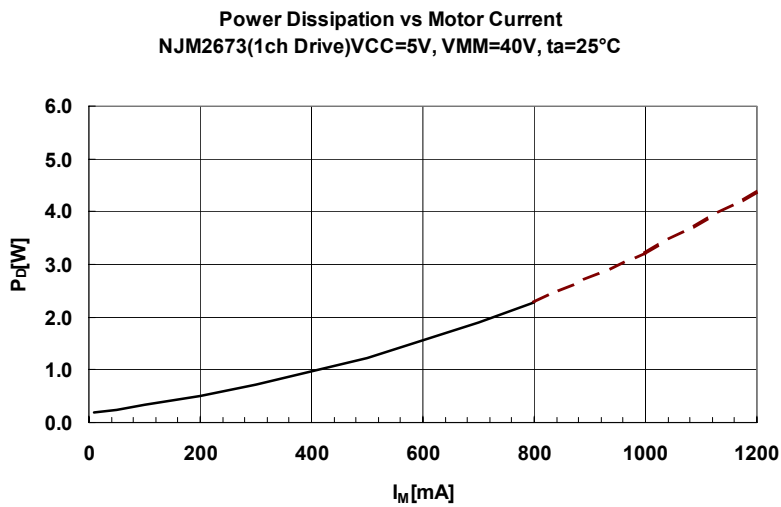
COMP input Voltage VS. COMP input Current  
@NJM2673 VCC=VR=5V I<sub>0</sub>=HIGH I<sub>1</sub>=LOW



Phase input Voltage VS. Phase input Current  
@NJM2673 VCC=VR=5V



■ TYPICAL CHARACTERISTICS



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